

SIGGRAPH 2001 Course 38: A Practical Guide to Global Illumination using Photon Mapping

Visual Importance and the Photon Map

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What is Visual Importance ?

- Parts of the scene important for a certain view



View Importance

Illumination (photon map)

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Goal

- Importance driven algorithms:

Use importance to optimize storage and computation (view dependent)

- Previous work:
 - Peter '98, Suykens '00, Keller '00, Christensen '01

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Overview

- Algorithm:

```

compute importance maps & required density
while (photons to trace)
  for each photon hit :
    if (current density(pos) < required(pos))
      store photon
    else
      distribute photon power
rendering pass => image

```

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- Importance math & physics
- Importance maps
- Required density
- Alternative: Path Differentials

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Importance: Math & Physics

- Importance = dual of light



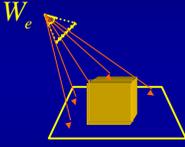
Radiance:

$$L(x, \vec{w}) = L_e(x, \vec{w}) + \int_{\Omega_x} L_r(x, \vec{w}') f_r(x, \vec{w}, \vec{w}') \cos(n_x, \vec{w}') d\omega'$$

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Importance: Math & Physics

- Importance = **dual of light**



'Potential':

$$W(x, \vec{w}) = W_e(x, \vec{w}) + \int_{\Omega_i} W_i(x, \vec{w}') f_r(x, \vec{w}, \vec{w}') \cos(n_x, \vec{w}') d\vec{w}'$$

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Importance: Math & Physics

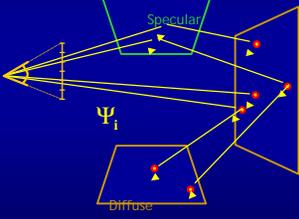
- Importance transport == Light transport

	Importance	Light
Quantities	Potential 'W'	Radiance 'L'
	(Incoming) Importance 'Γ'	Irradiance 'E'
	Importance Flux 'Ψ'	Flux/Power 'Φ'

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Importance Maps

- Very similar to constructing photon maps
- Shoot 'importons', store on non-specular objects



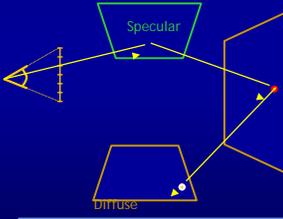
Importon flux:

$$\Psi_i = \frac{\Psi_{screen}}{N_{importons}}$$

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Importance Maps

- Two photon maps ⇒ Two importance maps
 - Caustic map : direct visualisation
 - Global map : indirect visualisation (final gather)



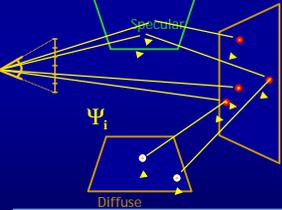
Would read caustic map ⇒
Caustic importance map

Would read global map ⇒
Global importance map

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Importance Maps

- Two photon maps ⇒ Two importance maps
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Caustic importance map
 $E(S^*)D$

Global importance map
 $E(S^*)D(S^*)D$

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Importance Maps

- Importance reconstruction: Γ



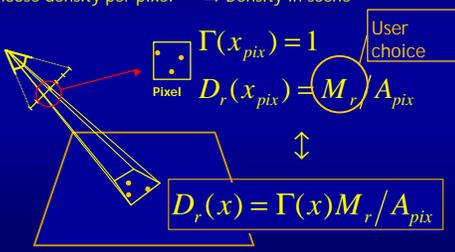
Find M nearest importons :

$$\Gamma(x) \approx \frac{\sum_{i=1}^M \Psi_i}{Pr_M^2(x)}$$

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Required Density

- High importance \Rightarrow High density D_r
- Heuristic : Linear relationship ($D_r = c \cdot \Gamma$)
- Choose density per pixel \Rightarrow Density in scene



$$\Gamma(x_{pix}) = 1$$

$$D_r(x_{pix}) = M_r / A_{pix}$$

$$D_r(x) = \Gamma(x) M_r / A_{pix}$$

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Required Density

$$D_r(x) = \Gamma(x) M_r / A_{pix}$$

- Caustic Map: $M_r = 10 - 30$
- Global Map: $M_r = 1 - 2$
- $\Gamma(x)$ requires importance map lookup: balanced kd-tree



Caustic importance map

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Overview

- Algorithm:
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 - for each photon
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 - store photon
 - else
 - Alternative: Path Differentials
 - distribute photon power
- rendering pass \Rightarrow image

- Importance math & physics
- Importance maps
- Required density
- Alternative: Path Differentials

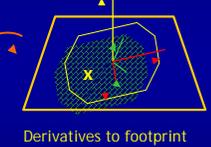
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Importance Map Alternative

- Path differentials : Trace 'footprint' of a pixel (or region of influence of a path)



Partial derivatives
(pixel, BRDF sampling)



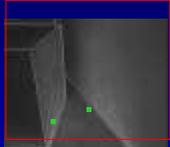
Derivatives to footprint

$$\Gamma_{pix}(x) \sim \frac{1}{A_{footprint}}$$

Suykens, EGWR '01
Igehy, Siggraph '99

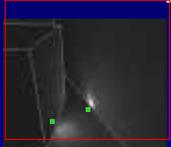
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Pixel vs. Screen Importance



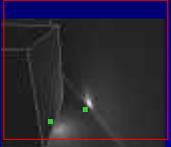
Screen importance
= importance map

Bound on screen error



Pixel importance
= importance map per pixel

Bound on pixel error



Path differentials
= importance from a single path

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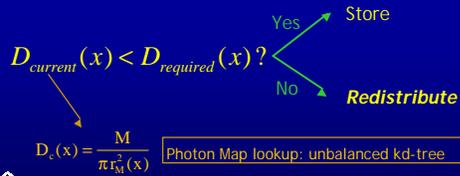
Overview

- Algorithm:
 - compute importance maps & required density
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Photon Map Construction

- Shoot photons as usual
- For each hit :
compare current & required density

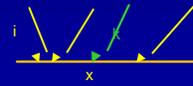


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Power redistribution

Photon 'k' arrives at 'x':



Reconstruction in 'x', M nearest photons + photon 'k':

$$\tilde{L}_r(x, \omega) = \frac{\sum_{i=1}^M \Phi_i \cdot f_r(x, \omega_i, \omega) + \Phi_k \cdot f_r(x, \omega_k, \omega)}{\pi r_{M+1}^2(x)}$$

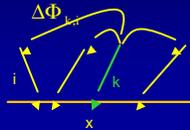


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Power redistribution

Photon not stored:



Reconstruction in 'x' after distribution:

$$\tilde{L}_r(x, \omega) = \frac{\sum_{i=1}^M f_r(x, \omega_i, \omega) (\Phi_i + \Delta\Phi_{k,i})}{\pi r_M^2(x)}$$



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Power redistribution

- Choice for $\Delta\Phi_{k,i}$ can be based on:
 - distance to 'x'
 - photon direction
- $\Delta\Phi_{k,i} = \Phi_k / M'$ for M' photons i that contribute in x (cosine w. normal > 0)
(Diffuse: equal reconstruction in 'x')
- Extra bias (splatting), but current density high enough + M small (± 20)

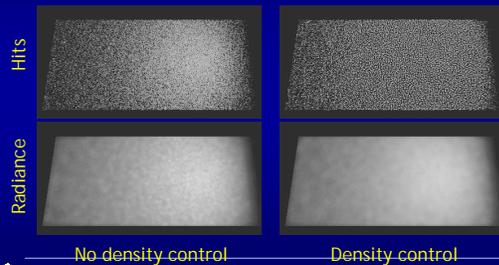


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Power redistribution

- Result (D_r constant)



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Overview

- **Algorithm:**

```

compute importance maps & required density
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      distribute photon power
      
```
- rendering pass ⇒ image



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Rendering pass

- Redistribution maintains energy balance
- Photon powers may differ, but
 - Gradual change (homogeneous map)

▷ No change in rendering pass

- But could use importance ?!?!

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Results

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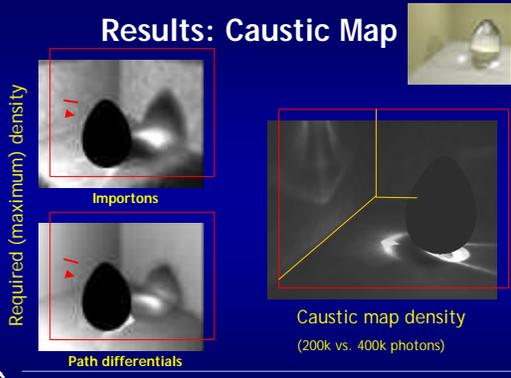
Results: Caustic Map



Final Image

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Results: Caustic Map

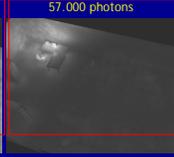


Caustic map density
(200k vs. 400k photons)

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Results: Global Map

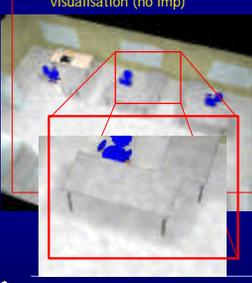
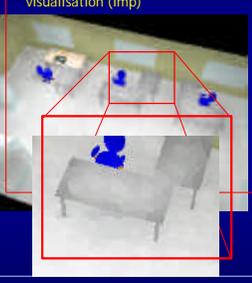


80,000 importons	400,000 photons	57,000 photons
		
Required density	Photon map density (normal)	Photon map density (importance driven)

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Results: Global Map



Global map, direct visualisation (no imp)	Global map, direct visualisation (imp)
	

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Results: Global Map





Standard



Importance driven

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Conclusions

- Visual importance
 - ⇒ More compact photon map
- Redistribution: number of photons limited
 - Trace until difficult region ok
 - (Arbitrary memory gain)
- Steps towards automatic 'error control'
- BUT: Still a lot to find out...

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Future work

- Required density: dependent on 'other' illumination?



Caustic Map



All illumination

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Future work

- Required density: take glossiness into account



Global map density



Global map radiance

Directional importance ?

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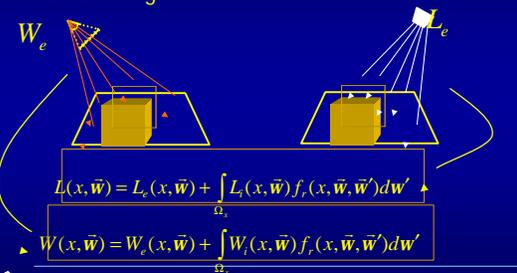
Future work

- Shoot fewer photons (homogeneous map!)
 - Per Christensen
- How many nearest photons ?
- Participating media
- ...

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What is Visual Importance ?

- Dual of light



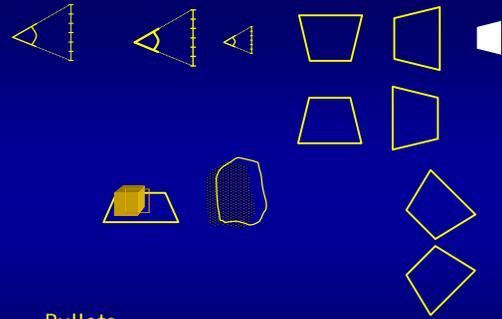
$$L(x, \vec{w}) = L_e(x, \vec{w}) + \int_{\Omega_r} L_i(x, \vec{w}') f_r(x, \vec{w}, \vec{w}') d\vec{w}'$$

$$W(x, \vec{w}) = W_e(x, \vec{w}) + \int_{\Omega_r} W_i(x, \vec{w}') f_r(x, \vec{w}, \vec{w}') d\vec{w}'$$

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Overview

- Visual importance: what & why
- Computing visual importance :
 - Importance maps
- Photon map construction
 - Density Control
- Rendering
- Conclusions & open issues



- Bullets

